PETROLOGY AND SM–ND CHRONOLGIES OF A BASALTIC EUCRITE, NWA 7188. S. Kagami[1], T. Yokoyama[1], T. Usui[2], and M. K. Haba[1], [1]Department of Earth and Planetary Sciences, Tokyo Institute of Technology, (2-12-1 Ookayama, Meguro-ku, Tokyo 152-8551, Japan, e-mail: kagami.s.ab@m.titech.ac.jp), [2]Earth-Life Science Institute, Tokyo Institute of Technology.

Introduction: Eucrites are differentiated achondrites that most likely originated from the crust of asteroid 4-Vesta. Because most eucrites have experienced various thermal metamorphisms and/or impact events on the parent body [1, 2], radiometric dating of eucrites (e.g., Rb–Sr, U–Pb) presumably provides the timings of secondary events rather than that of initial crystallization. Samarium–Nd systematics has some advantages for dating eucrites. First, Sm and Nd are not significantly fractionated from each other during secondary events due to their chemical similarity. Second, Sm–Nd systematics has two chronometers that utilize a long-lived ^{147}Sm ($T_{1/2}$ = 1.06×10^{11} yr) with a daughter nuclide ^{143}Nd and a short-lived ^{146}Sm ($T_{1/2}$ = 1.03×10^{8} yr) with a daughter nuclide ^{142}Nd. In some situations, ^{147}Sm–^{143}Nd ages of eucrites have been significantly affected by secondary events whereas the ^{146}Sm–^{142}Nd systematics has not been disturbed, in which case the latter would retain the older crystallization age rather than the metamorphic age [3, 4]. However, there is paucity of precise Sm–Nd ages of eucrites with age uncertainties of less than 50 Ma [5, 6]. The oldest and most precise ^{146}Sm–^{142}Nd mineral isochron age of basaltic eucrite hitherto available has been obtained from Caldera, which has shown 4548 $^{+21}/_{-24}$ Ma (^{146}Sm/^{144}Sm = 0.0073 ± 0.0011) [7].

In this study, we investigate the petrology and the ^{147}Sm–^{143}Nd and ^{146}Sm–^{142}Nd chronologies of a basaltic eucrite, Northwest Africa (NWA) 7188. This meteorite was found in 2011 and has been studied by limited researchers until now [8, 9]. It is important to examine the geochemical characteristics of NWA 7188 because this basaltic eucrite is non-Antarctic and unweathered meteorite with relatively small effect of brecciation. The objective of this study is to obtain highly precise ^{147}Sm–^{143}Nd and ^{146}Sm–^{142}Nd ages and constrain the period of igneous activity of basaltic crust on the eucrite parent body.

Samples: Two specimens of NWA 7188 (60 mm × 80 mm × 8 mm and 25 mm × 30 mm × 3 mm) used in this study had intersertal texture composed of plagioclase, pigeonite, and minor minerals. We prepared two chips from these specimens that were used for (i) making a polished thin section that was used for mineralogical observations and (ii) mineral separation for conducting the Sm–Nd dating. The latter one (~20 g) was crushed and sieved into four sizes; G1) 250–500 µm, G2) 106–250 µm, and G3) 45–106 µm. The G2 and G3 fractions were separated into magnetic and non-magnetic minerals, respectively. Pyroxenes were handpicked from the magnetic fractions, and plagioclases were from the non-magnetic fractions.

Experimental: The polished thin section was examined using a scanning electron microprobe (SEM) (Hitachi S-3400N) with an energy dispersive spectrometer (EDS) and using an electron microprobe analyzer (EPMA) (JEOL-JXA-8530F) both installed at Tokyo Tech. Mineral modes were determined with an image analysis software, JMicroVision.

G1 and separated mineral fractions (G2 and G3) were cleaned with acetone and Milli-Q water and then powdered using an agate mortar and pestle. The powdered sample of the G1 fraction was decomposed using a high-pressure digestion system (DAB-2, Berghof) with concentrated HF and HNO_3 to completely dissolve refractory minerals such as zircon. Subsequently, the samples were treated with $HClO_4$ to eliminate insoluble fluorides. The G2 and G3 fractions were digested by following the method described in [10]. After the sample digestion, ~10% of the solution was split for determination of the Sm/Nd ratios with isotope dilution using a quadrupole ICP-MS at Tokyo Tech (X-series II, Thermo) [11]. The remainder of the sample solution was processed for high-precision Nd isotope analysis using TIMS at Tokyo Tech (TRITON plus) with the dynamic multicollection method [12].

Results and Discussion: The elemental mappings obtained from SEM analysis indicated that NWA 7188 consisted of plagioclase (~40%), pyroxene (~55%), and minor minerals (silica minerals, ilmenite, spinel, apatite, troilite). Most pyroxenes had sub-µm lamellas. The compositions of pyroxene and plagioclase from EPMA analysis ranged from $Wo_{3.3}En_{33.9}Fs_{62.8}$ to $Wo_{37.5}En_{30.0}Fs_{32.5}$ and from $Or_{2.0}Ab_{20.0}An_{78.0}$ to $Or_{0.2}Ab_{7.4}An_{92.4}$, respectively.

The Fe/Mn ratios of pyroxenes were relatively homogeneous at ~0.031 (N = 88), suggesting that NWA 7188 experienced a series of igneous processing on the parent body [13]. Moreover, the mean Fe/Mn ratio was consistent with those of most basaltic eucrites (Fig. 1) [14]. The consistency of Fe/Mn ratios in pyroxenes with the other basaltic eucrites is one of the important evidence that support the genetic linkage between this meteorite and normal eucrites [15].

The ^{147}Sm–^{143}Nd and ^{146}Sm–^{142}Nd isochrons of NWA 7188 yielded the ages of 4584 ± 200 Ma

(MSWD = 1.3), and 4561 $^{+12}/_{-13}$ Ma (^{146}Sm/^{144}Sm = 0.0079 ± 0.0007, MSWD = 2.0) determined by assuming an initial solar system ratio of ^{146}Sm/^{144}Sm = 0.0083 at 4567 Ma [16], respectively (Figs. 2 and 3). The ^{147}Sm–^{143}Nd and ^{146}Sm–^{142}Nd isochron ages are consistent with each other within analytical uncertainties. The ^{146}Sm–^{142}Nd age obtained here is older than that of Caldera, the timing that most likely corresponding to the early crystallization [3]. This result suggests that the ^{146}Sm–^{142}Nd isochron age of NWA 7188 represents the crystallization age. Therefore, pyroxenes and plagioclases contained in the G2 and G3 fractions of NWA 7188 could have preserved the information regarding the timing of initial crystallization of basaltic eucrites in the early Solar System.

We calculated the ^{146}Sm–^{142}Nd whole-rock isochron for eucrites using the data reported by [11, 17], which yielded 4556 $^{+19}/_{-22}$ Ma with ^{146}Sm/^{144}Sm = 0.0077 ± 10 (MSWD = 5.9). This age is considered to be the timing of Vesta's crust formation. Therefore, the timing of Vesta's crust formation and the crystallization of basaltic eucrites would be contemporaneous. In addition, the slope of the ^{146}Sm–^{142}Nd mineral isochron for a cumulate eucrite Binda gave a ^{146}Sm/^{144}Sm ratio of 0.0073 ± 5 (MSWD = 1.6) in [18], which corresponded to 4548 $^{+11}/_{-12}$ Ma. The crystallization age of basaltic eucrite is older than that of cumulate eucrites although the analytical uncertainties are overlapped. This difference would reflect that the cooling rate of the source reservoir for basaltic eucrites was faster than that of cumulate eucrites.

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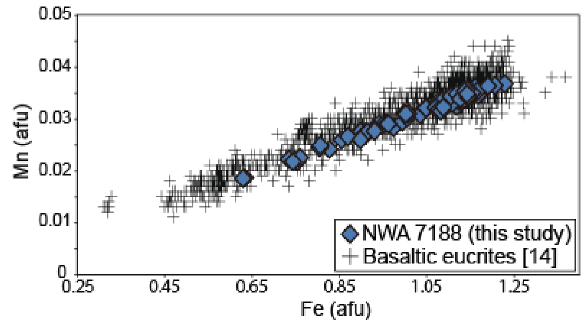

Fig. 1 *Mn versus Fe per 6-oxygen formula unit for pyroxene in basaltic eucrites.*

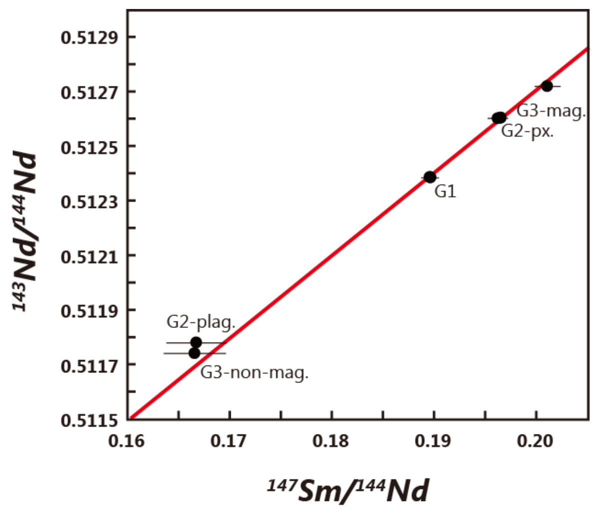

Fig. 2 *^{147}Sm-^{143}Nd isochron diagram of NWA 7188. Error bars are 2SE, of which the x- and y- axis is smaller than the size of symbols. MSWD is 1.3.*

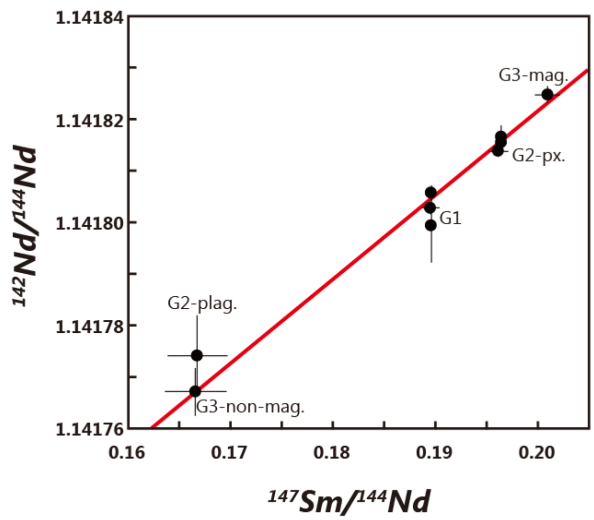

Fig. 3 *^{146}Sm-^{142}Nd isochron diagram of NWA 7188. Error bars are 2SE. MSWD is 2.0.*